ZnO Piezoelectric Nanowires for Use in a Self-Powered Structural Health Monitoring Device for Fiber-Reinforced Composites Uploading Attachment Instructions

Completed Technology Project (2016 - 2018)

Project Introduction

The goal of this proposed research is to develop a new self-powered structural health monitoring (SHM) system for fiber-reinforced polymer (FRP) composites by using piezoelectric zinc oxide (ZnO) nanowires grown directly into the composite. This new SHM system can increase the safety and reliability of existing aerospace structures, reduce current maintenance costs, and improve several material properties of composites used in aerospace structures. Specifically, the proposed work will (1) investigate multiple methods of growing ZnO nanowires in FRP composites on a large scale, (2) quantify the power generation of the ZnO nanowires in FRP composite samples for use in energy harvesting (EH), and (3) determine the accuracy of the piezoelectric ZnO nanowires in detecting the location and extent of damage for SHM in FRP composites. This work is relevant due to its broad application in aerospace structures. FRP composites are increasing in use in the aeronautical and aerospace industries due to their high strength-to-weight ratio, but they are subject to damage. Because of this risk, attention has been given to SHM which uses piezoelectric materials to obtain real-time information regarding the overall damage condition of a structure. The sensors or systems of sensors used in SHM require a power source which may be difficult to provide, replace, or dispose of which further motivates EH, or the harvesting and application of power generated by piezoelectric materials during the ambient vibrations of a structure. The proposed research combines the preliminary research and technology developed into a comprehensive self-powered SHM system using piezoelectric nanowires for application in aerospace structures. To accomplish the stated objectives, a series of tasks are proposed. The first task is to build upon and improve existing techniques for growing ZnO nanowires on test coupons to facilitate application on larger samples. This will be done by investigating the use of an atomizer to create a fine mist for deposition of an initial layer of amorphous ZnO for seeding. The ZnO nanowires will then be grown using a low temperature hydrothermal synthesis technique, and the multi-layer carbon fiber reinforced composites will be fabricated using a hand-layup system. The second task is to quantify the amount of power generated by the larger scale piezoelectric ZnO samples and implement techniques to increase the strain of the sample thus increasing power generation. The multi-layer composites will be placed in a cantilever configuration and excited at their first natural frequency with a range of applied impedance loads. Ohm's Law will then be used to calculate the power generated. Increasing the size of the sample, adding tip mass, and increasing the base excitation rate will all be investigated in order to increase the power generated by the piezoelectric nanowires. The third task is to determine and analyze the use of the ZnO samples in impedance testing for SHM by applying a range of high frequency vibrations and using an impedance analyzer. A controlled amount of damage will be applied to the samples varying in extent and location and the corresponding impedance data from the analyzer will be evaluated in order to determine damage correlation. Due to the electromechanical coupling of the

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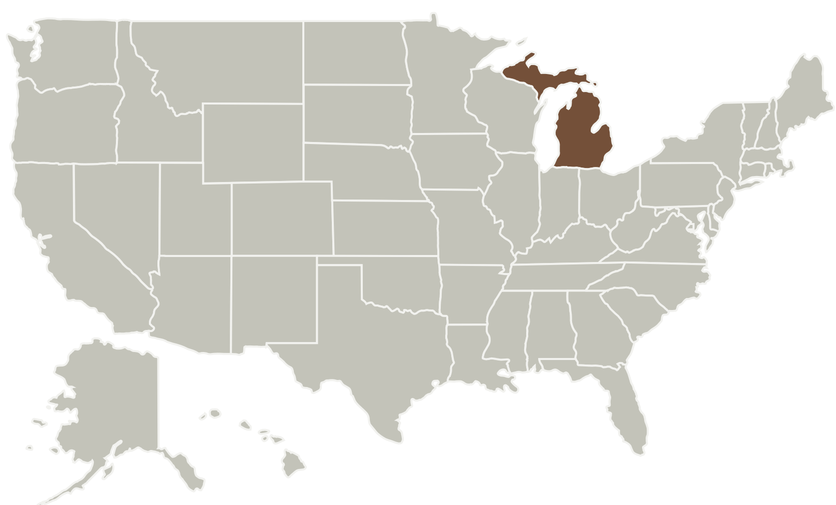
nanowires, change in the mechanical impedance (i.e. damage) of the structure will correlate with change in the electrical impedance of the signal. The fourth task will then be the analysis of ZnO samples in SHM using the guided wave method. Using the piezoelectric nanowires simultaneously as sensors and actuators, an electrical signal can be both sent and received by an organized array of nanowires. Any reflection or alteration of the sensed signal will indicate an interaction with damage in the structure. A combination of both the impedance and guided wave methods will then be reviewed for an accurate and effective SHM system.

Anticipated Benefits

This new SHM system can increase the safety and reliability of existing aerospace structures, reduce current maintenance costs, and improve several material properties of composites used in aerospace structures.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Michigan-Ann Arbor	Lead Organization	Academia	Ann Arbor, Michigan

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

University of Michigan-Ann Arbor

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Daniel Inman

Co-Investigator:

Lorianne Groo

Primary U.S. Work Locations

Michigan

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**

1 2 3 4 5 6 7 8 9

Applied Research | Development | Demo & Test

Technology Areas

Primary:

- TX11 Software, Modeling, Simulation, and Information Processing
  - └ TX11.3 Simulation
    - └ TX11.3.7 Multiscale, Multiphysics, and Multifidelity Simulation

Target Destination

Foundational Knowledge